$$LS^N = \begin{bmatrix} C^N & S^N \\ C^N & -S^N \end{bmatrix} = \begin{bmatrix} LS_0^N \\ \cdot \\ \cdot \\ \cdot \\ LS_K^N \\ \cdot \\ \cdot \\ \cdot \\ LS_{N-1}^N \end{bmatrix} \quad \text{... Equation 1.}$$

Herein, LS^N is an orthogonal spreading code matrix, LS_K^N is a row vector having a size of 1XN representing the Kth orthogonal spreading code, C^N and S^N are sub-matrices respectively having a size of $\frac{N}{2} \times \frac{N}{2}$, and K is 0 to N-1. S^N is recursively obtained from C^N,and C^N is recursively obtained from $C^{\frac{N}{2}}$.

Meanwhile, when a guard component L_{GUARD} having a size of $\frac{N}{2} \times L_{GUARD}$ is inserted after or before C^N and S^N for generating the IFW, an orthogonal spreading code can be expressed as in Equation 2, wherein the length of a code is $N+2\times L_{GUARD}$, m is a natural number at least 2, and the length of guard component is an integer at least 0.

$$LS^{N+2\times L_{GUARD}} = \begin{bmatrix} 0^{L_{GUARD}} & C^N & 0^{L_{GUARD}} & S^N \\ 0^{L_{GUARD}} & C^N & 0^{L_{GUARD}} & -S^N \end{bmatrix}$$

$$= \begin{bmatrix} LS_0^{N+2\times L_{GUARD}} \\ \cdot \\ \cdot \\ \cdot \\ LS_K^{N+2\times L_{GUARD}} \\ \cdot \\ \cdot \\ \cdot \\ LS_{N-1}^{N+2\times L_{GUARD}} \end{bmatrix} \quad \ldots \text{ Equation 2.}$$

Herein, $LS^{N+2\times L_{GUARD}}$ is the orthogonal spreading code matrix, $LS_K^{N+2\times L_{GUARD}}$ is a row vector expressing the Kth orthogonal spreading code having a size of $1\times(N+2\times L_{GUARD})$. Also, $0^{L_{GUARD}}$ is a row vector having a value of 0 and a size of $\frac{N}{2}\times L_{GUARD}$.

If the IFW of the orthogonal code has an interval of $[-L_{IFW},L_{IFW}]$, the number of the orthogonal spreading codes is 2^{m-g} when $2^{g-1} \le L_{IFW} \le 2^g$. Herein, g is a natural number, m is a natural number at least 2, L_{IFW} and L_{GUARD} have the following relation: $L_{GUARD} \ge L_{IFW} \ge 0$.

The following detailed description will present a code allocating method for increasing the length of the IFW and a code pair generating method for minimizing the phase transition of 180 degree among the codes allocated to I branch and the codes allocated to Q branch to minimize a Peak-to-Average Power Ratio (PAPR).

Generation of Orthogonal Code Set

Equation 2 shows that total 2^g number of orthogonal code sets (O) as sets of mutually orthogonal codes exist, and each of the orthogonal code sets includes 2^{m-g} number of elements.

Therefore, the orthogonal code sets can be expressed as in Equation 3:

$$O_1 = \{LS_0^{N+2\times L_{GUARD}}, LS_1^{N+2\times L_{GUARD}}, \cdots, LS_{2^{m-g}-1}^{N+2\times L_{GUARD}}\},$$

$$O_2 = \{LS_{2^{m-g}}^{N+2\times L_{GUARD}}, LS_{2^{m-g}+1}^{N+2\times L_{GUARD}}, \cdots, LS_{2^{m-g}+2^{m-g}-1}^{N+2\times L_{GUARD}}\},$$

.,

.,

.,

$$O_K = \{LS_{(K-1)\times 2^{m-g}}^{N+2\times L_{GUARD}}, LS_{(K-1)\times 2^{m-g}+1}^{N+2\times L_{GUARD}}, \cdots, LS_{(K-1)\times 2^{m-g}+2^{m-g}-1}^{N+2\times L_{GUARD}}\},$$

.,

.,

., and

$$O_{2^g} = \{LS_{(2^g-1)\times 2^{m-g}}^{N+2\times L_{GUARD}}, LS_{(2^g-1)\times 2^{m-g}+1}^{N+2\times L_{GUARD}}, \cdots, LS_{(2^g-1)\times 2^{m-g}+2^{m-g}-1}^{N+2\times L_{GUARD}}\} \quad \text{... Equation 3.}$$

As shown in Equation 3, the total 2^g number of orthogonal code sets exist from O_1 to O_{2^g}. Therefore, the same autocorrelation and crosscorrelation characteristics can be expressed even if any one is selected from the orthogonal code sets. However, all of the orthogonal code sets are not used at the same time, but only one set is used. In other words, if the orthogonal code set O_1 is used, the remaining orthogonal code sets are not used by the following reason: When several orthogonal code sets are used at the same time, the autocorrelation and crosscorrelation characteristics are not maintained in the IFW.

Therefore, when a representative orthogonal code set is shown as L, each of element in the set is defined as: $L = \{l_0, l_2, \cdots, l_{2^{m-g}-2}, l_{2^{m-g}-1}\}$. Then, each elements between the orthogonal code sets O_k and the representative orthogonal code set L can be

one-to-one matched in the ascending order.

In other words, the representative orthogonal code set is L=O_1 when O_1 is selected as the orthogonal code set. Then, elements in the orthogonal code set can be expressed as in Equation 4:

$l_0 = LS_0^{N+2\times L_{GUARD}}$,

$l_1 = LS_1^{N+2\times L_{GUARD}}$,

.,

.,

., and

$l_{2^{m-g}-1} = LS_{2^{m-g}-1}^{N+2\times L_{GUARD}}$ ... Equation 4.

Therefore, the representative orthogonal code set can be expressed as $L = O_1 = \{l_0, l_1, \cdots, l_{2^{m-g}-1}\}$.

When O_k is selected as the orthogonal code set, the representative orthogonal code set becomes L=O_k, and the elements in the orthogonal code set can be expressed as in Equation 5:

$l_0 = LS_{(K-1)\times 2^{m-g}}^{N+2\times L_{GUARD}}$,

$l_1 = LS_{(K-1)\times 2^{m-g}+1}^{N+2\times L_{GUARD}}$,

.,

.,

., and

$l_{2^{m-g}-1} = LS_{(K-1)\times 2^{m-g}+2^{m-g}-1}^{N+2\times L_{GUARD}}$ ... Equation 5.

As a result, in order to generate the IFW, the orthogonal code sets can be generated by using the orthogonal spreading codes, which include the guard components according to Equations 2, 3 and 5.

As described above, spreading methods using the orthogonal spreading codes include: a Binary Phase Shift Keying (BPSK) spreading method in which the same orthogonal spreading code is used in both I branch and Q branch (Fig. 1), a Quadrature Phase Shift Keying (QPSK) spreading method in which different orthogonal spreading codes are allocated to the I branch and the Q branch (Fig. 2), and a complex spreading method for reducing the power imbalance between the I and Q branch (Fig. 3).

The following description will present a method for generating the optimum code pairs and allocating the codes using the orthogonal code sets. For convenience's sake, firstly the description will be made about a situation in which different orthogonal spreading codes are used in the I and Q branch, and then a situation in which the same orthogonal spreading code is used in the I and Q branch.

<u>Optimum Code Pair Allocation (Using Different Spreading Codes)</u>

(1) Minimizing the PAPR (S 63 in Fig. 5)

As described above, when the different spreading codes are used in each of the I component and the Q component, the spreading codes of the I and Q component can be varied simultaneously. Then the spreaded signal may undergo a phase transition of 180 degree, thereby increasing the Peak-to-Average Power Ratio (PAPR). Therefore, when the different orthogonal spreading codes are used in each of the I and Q branch, code pairs are so generated to minimize the 180 degree phase transition of each signal. In other words, when the orthogonal spreading codes are used for spreading, the optimum code pairs are so selected to minimize the 180 degree phase transition between

the I and Q branch codes in selecting each spreading code pair (I_{branch} code, Q_{branch} code) or (Q_{branch} code, I_{branch} code) in an orthogonal code set.

For example, the code pairs allowing the minimum phase transition of the 180 degree between the I and Q branch codes can be expressed as in Equation 6:

$$(I_{branch}, Q_{branch}) or (Q_{branch}, I_{branch})$$

$$= (l_0, l_{2^{m-g-1}}), (l_1, l_{2^{m-g-1}+1}), \cdots, (l_{2^{m-g-1}-1}, l_{2^{m-g}-1}) \quad \ldots \text{ Equation 6,}$$

wherein O_1 is selected from the orthogonal code sets, and thus the representative set is expressed as: $L = O_1 = \{l_0, l_0, \cdots, l_{2^{m-g}}, l_{2^{m-g}-1}\}$. If the other orthogonal code set is selected as the representative orthogonal code set, the equation 6 would be changed according to the selected representative orthogonal code set.

Therefore, the code pairs can be generated on the basis of the center of the orthogonal code set which are arrayed in the ascending order. In other words, the first element of the orthogonal code set arrayed in the ascending order is paired with the first element from the center, and the second element of the orthogonal code is paired with the second element from the center. Finally, the element right before the center is paired with the last element of the orthogonal code set. For example, when m is 8 and g is 5, the representative set is $L = O_1 = \{l_0, l_1, l_2, l_3, l_4, l_5, l_6, l_7\}$ having 8 elements. Then, the code pairs can be respectively generated as $(l_0, l_4), (l_1, l_5), (l_2, l_6), (l_3, l_7)$.

The generated code pairs can be allocated in the ascending order according to generation. In other words, the first generated code pair (l_0, l_4) is allocated, the next generated code pair (l_1, l_5) is followed, and finally (l_3, l_7) is allocated.

Alternatively, after the orthogonal code sets are grouped into code pair sets, the

code pairs are allocated to the code pair sets. In other words, the code pair sets can be indicated P and expressed as in Equations 7 and 8:

$P=\{(Code_{left}, Code_{right})$ or $(Code_{right}, Code_{left})$

$=(I_{branch}, Q_{branch})$ or $(Q_{branch}, I_{branch})\}$ … Equation 7, and

$P=\{(l_0, l_{2^{m-g-1}}), (l_1, l_{2^{m-g-1}+1}), \cdots, (l_{2^{m-g-1}-1}, l_{2^{m-g}-1})\}$ … Equation 8.

Herein, Equations 8 shows the code pair set grouped in reference to Equation 6.

At this time, note that there are no restrictions in the order of allocating the code pairs in the code pair set. Namely, according to such code pair allocation, any code pair can be primarily allocated in the code pair set.

(2) Increasing the Length of the IFW (S 65 in Fig. 5)

The invention relates to a method for sequentially allocating orthogonal spreading codes to extend the length of the IFW, in which the length of the IFW is extended when halves of the total available codes or less are used.

Supposing that O_1 is selected from the orthogonal code sets and thus the representative orthogonal code set is indicated as $L=O_1=\{l_0, l_1, \cdots, l_{2^{m-g}-2}, l_{2^{m-g}-1}\}$, the code pair set P is defined as Equation 7:

When the halves of the total available codes or less are used, the code pair sets can be grouped into P_1 and P_2, and each of the code pair sets can be expressed as in Equations 9 and 10.

$P_1=\{(l_0, l_{2^{m-g-2}}), (l_1, l_{2^{m-g-2}+1}), \cdots, (l_{2^{m-g-2}}, l_{2^{m-g-1}-1})\}$ … Equation 9, and

$P_2=\{(l_{2^{m-g-1}}, l_{2^{m-g-1}+2^{m-g-2}}), (l_{2^{m-g-1}+1}, l_{2^{m-g-1}+2^{m-g-2}+1}),$

$\cdots, (l_{2^{m-g-1}+2^{m-g-2}-1}, l_{2^{m-g}-1})\}$ … Equation 10.

As shown in Equations 9 and 10, the elements of the orthogonal code set, which is arrayed in the ascending order, are divided into halves, in which elements in a lower order are grouped as P_1, and elements in the next order are grouped as P_2. Generation of code pairs from P_1 and P_2 can be expressed as in Equation 6. Description will be made in reference to the code pairs from P_1.

First, P_1 includes those in the lower order up to the center from the elements arrayed in the ascending order. The elements up to the center are paired on the basis of the quarter center: the first element of the orthogonal code set arrayed in the ascending order is paired with the first element from the quarter center; and the second element is paired with the second element from the quarter center. Finally, the element before the quarter center is paired with the last element of the orthogonal code set. Herein, when the elements included in the representative set are N, the center is a portion that is indicated as N/2, and the quarter center is a portion that is indicated as N/4.

As a result, after the halves of the total available codes or less are used, the code pair sets are grouped based upon the orthogonal code sets, one code pair set is selected from at least one code pair sets. The code pairs are allocated based upon the selected code pair set. Herein, in the order of allocating the code pairs, any code pair may be freely allocated to the code pair set.

Therefore, the method for allocating the codes as set forth above has the following effect: when a small number of channels are used and thus the code pair allocation is carried out in one of the code pair sets, the length of the IFW is extended.

(3) Optimum Code Allocation (Using Same Spreading Code) (S 68 in Fig. 5)

The invention is devised to obtain an effect that the length of the IFW is extended when the same spreading code is used in both I and Q branch and the halves of

the total available codes (N) or less are used. Herein, it should be noticed that the foregoing code pair generation is unnecessary since the same spreading code is used.

For example, when the representative set is expressed as $L = \{l_0, l_1, \cdots, l_{2^{m-g}-2}, l_{2^{m-g}-1}\}$, code sets can be defined as in Equation 11:

$$L_1 = \{l_0, l_1, l_2, l_3\},$$

$$L_2 = \{l_4, l_5, l_6, l_7\},$$

$$L_3 = \{l_8, l_9, l_{10}, l_{11}, l_{12}, l_{13}, l_{14}, l_{15}\},$$

$\cdot,$

$\cdot,$

$\cdot,$

$$L_k = \{l_{2^k}, l_{2^k+1}, l_{2^k+2}, \cdots, l_{2^{k+1}-2}, l_{2^{k+1}-1}\} \cdot,$$

$\cdot,$

$\cdot,$

$\cdot,$

$$L_{m-g-1} = \{l_{2^{m-g-1}}, l_{2^{m-g-1}+1}, l_{2^{m-g-1}+2}, \cdots, l_{2^{m-g}-2}, l_{2^{m-g}-1}\} \quad \ldots \text{ Equation 11.}$$

Herein, L_K can be expressed only if K is a natural number from 2 to m-g-1. Therefore, if K is 1, L_1 will de defined separately from the foregoing.

Therefore, describing allocation of the codes from Equation 11, one code set is selected from the code sets in the ascending order, and the code can be freely chosen from the selected code set without any fixed order. For example, L_1 is primarily selected, and then the codes from L_1 is allocated without any fixed order. After allocating all the elements included in L_1, L_2 is selected to determine the order of

allocating elements included in L_2. The same process is carried out in the last code set L_{m-g-1} to determine the order of allocation.

Therefore, the method for allocating the codes as set forth above has an effect that the length of the IFW is extended when halves of the total available codes or less are used.

Fig. 4 is a flow chart for illustrating a method for generating a representative orthogonal code set using an orthogonal spreading code in accordance with a preferred embodiment of the invention, in which generation of the representative orthogonal code set can be more readily understood in reference to Equations 1 to 5.

Referring to Fig. 4, a given code length N equal or larger than 4 is selected in S 40. When the code length is selected, it is judged whether the code length N is 2^m in S 41 wherein m is equal or larger than 2. If it is judged that the code length N is 2^m, an orthogonal spreading code is generated in S 42. A code component length L_{GUARD} and an IFW length L_{IFW} are respectively selected in S 43 and S 44, and it is judged whether L_{GUARD} and L_{IFW} satisfy the relation $L_{GUARD} \geq L_{IFW} \geq 0$ in S 45. If it is judged that the relation $L_{GUARD} \geq L_{IFW} \geq 0$ is not satisfied, the foregoing S 43 is repeatedly executed until the relation $L_{GUARD} \geq L_{IFW} \geq 0$ is satisfied. If the relation $L_{GUARD} \geq L_{IFW} \geq 0$ is satisfied, execution is made to calculate g satisfying the relation $2^{g-1} \leq L_{IFW} \leq 2^g$ in S 46. If execution is so made that g satisfies the relation $2^{g-1} \leq L_{IFW} \leq 2^g$, k and j are respectively set up as 1 and 0 in order to discriminate the first orthogonal code set and set elements in S 47 and S 48.

The $(k-1)\text{x}2^{m-g}+j$th orthogonal spreading code is included as a set element to the kth orthogonal code set O_k in S 49.

After adding 1 to j in S 50, it is judged whether j is larger than $2^{m-g}-1$ in S 51.

If it is judged that j is not larger than 2^{m-g}-1, the foregoing S 49 is executed. If it is judged that j is larger than 2^{m-g}-1, 1 is added to k in S 52. It is judged whether k is larger than 2^g in S 53. If it is judged that k is not larger than 2^g, the foregoing S 49 is executed. If it is judged that k is larger than 2^g, one orthogonal code set is selected from 2^g number of orthogonal code sets to determine a representative orthogonal code set in S 54. Orthogonal code sets as in Equation 3 can be calculated from the foregoing Ss 47 to 53. One of the orthogonal code sets can be determined as the representative orthogonal code set in the foregoing S 54.